

IN THE SPECIFICATION

Please replace the paragraph beginning at page 10, line 22, with the following:

The VSE serves to clean the surface and break bonds of the oxide on the wafer surface. The VSE process can thus enhance the surface activation significantly. A desired bonding species can be ~~used to~~ terminated on surface 34 during the VSE by proper design of the VSE. Alternatively, a post-VSE treatment that activates and terminates the surface with a desired terminating species during the post-VSE process may be used.

Please replace the paragraph beginning at page 12, line 22, with the following:

FIGS. 4A-4E show surface conditions and the bonding propagation to form covalent bonds in a the case of a planar Si wafer covered with silicon oxide. On Si wafer 40 an SiO₂ layer 41 is formed, which has been polished and planarized. Surface 42 of layer 41 is subjected to the VSE process to produce an activated surface (FIG. 4A). On a second wafer 44 a second SiO₂ layer 45 is formed, and surface 46 is subjected to a VSE process to activate surface 46 (FIG. 4B). Desired species are terminated on surface 46 and are shown as lines 43 in FIG. 4C. Either or both of a VSE and post-VSE processes are used to properly terminate surface 46. While not shown, surface 42 may also be terminated using a post-VSE process. Wafer 44 is brought together with wafer 40 (FIG. 4D) and bonds 46 begin to form. ~~The the~~ bonding propagates and by-products are removed (indicated as arrows 47) and chemical bonds (such as covalent) are formed, as shown in FIG. 4E.

Please replace the paragraph beginning at page 17, line 5, with the following:

In the example of FIG. 2, the plasma treatment may create a damaged or defective area in the oxide layer near the bonding surface. The zone extends for a few monolayers.

The damaged or defective area aids in the removal of bonding by-products. Efficient removal of the bonding by-products improves the bonding strength since the by-products can interfere with the bonding process by preventing high-strength bond from ~~forming~~: forming.

Please replace the paragraph beginning at page 20, line 22, with the following:

In a second embodiment, the VSE process uses wet chemicals. For example, an InP wafer having a deposited silicon oxide layer, as in the first embodiment, and a device layer are bonded to a AlN substrate having a deposited oxide layer. After smoothing and planarizing the InP wafer bonding surface and the AlN wafer bonding surface, both wafers are cleaned in an standard RCA cleaning solution. The wafers are very slightly etched using a dilute HF aqueous solution with an HF concentration preferably in the range of 0.01 to 0.2%. About a few tenths of a nm is removed and the surface smoothness is not degraded as determined by AFM (atomic force microscope) measurements. Without deionized water rinse, the wafers are spin dried and bonded in ambient air at room temperature. The resulting bonding energy has been measured to reach $\sim 700 \text{ mJ/m}^2$ after storage in air. After annealing this bonded pair at 75°C the bonding energy of 1500 mJ/m^2 was ~~obtained~~, obtained. The bonding energy has been measured to reach silicon bulk fracture energy (about 2500 mJ/m^2) after annealing at 100°C . If the wafers are rinsed with deionized water after the HF dip, the bonding energy at 100°C is reduced to 200 mJ/m^2 , which is about one tenth of that obtained without the rinse. This illustrates the preference of F to OH as a terminating species.

Please replace the paragraph beginning at page 22, line 12, with the following:

The mechanisms governing the increased bond energy at low or room temperature are similar. A very slight etching (VSE) of the bonding wafers by plasma to clean and activate the surfaces, and improve removal of by-products of interface polymerization to prevent the undesirable reverse reaction and rinse in appropriate solution to terminate the surface with desired species to facilitate room temperature covalent bonding. The oxide covered wafer bonding case is similar except that a different surface termination is preferred. In bare silicon wafer bonding, the highly reactive surface layers of oxide and silicon to allow water adsorption and conversion to hydrogen should be formed. The highly reactive layers can be a plasma thin oxide layer and a damaged silicon surface layer. The oxide on the silicon wafer will also have some damage. Not only O₂ plasma but also plasma of other gases (such as Ar, CF₄) are adequate. Because during and after VSE the silicon surface is ~~readily~~ ready to react with moisture to form an oxide layer, and the underlying damaged silicon layer is created by VSE. Since the VSE and by-products removal methods are rather general in nature, this approach can be implemented by many means and apply to many materials.

Please replace the paragraph beginning at page 23, line 14, with the following:

Two wafers were loaded into the plasma system, both wafers are placed on the RF electrode and treated in plasma in RIE mode. For comparison, some wafers were treated in plasma mode in which the wafers were put on the grounded electrode. An oxygen plasma was used with a nominal flow rate of 16 scc/m. The RF power was 20-400 W (typically 80 W) at 13.56 MHz and the vacuum level was 100 mTorr. The oxide covered wafers were treated in plasma for times between 15 seconds to 5 minutes. The plasma treated silicon wafers were then dipped in an appropriate solution or ~~rinse~~ rinsed with de-ionized water

followed by spin-drying and room temperature bonding in air. Some of the plasma treated wafers were also directly bonded in air without rinse or dipping.

Please replace the paragraph beginning at page 49, line 2, with the following:

A method for bonding at low or room temperature includes steps of surface cleaning and activation by cleaning or etching. ~~One etching process~~ The method may also include removing by-products of interface polymerization to prevent a reverse polymerization reaction to allow room temperature chemical bonding of materials such as silicon, silicon nitride and SiO₂. The surfaces to be bonded are polished to a high degree of smoothness and planarity. VSE may use reactive ion etching or wet etching to slightly etch the surfaces being bonded. The surface roughness and planarity are not degraded and may be enhanced by the VSE process. The etched surfaces may be rinsed in solutions such as ammonium hydroxide or ammonium fluoride to promote the formation of desired bonding species on the surfaces.